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FIRE RETARDANT CHEMICALS ASSOCIATION

FIRE SAFETY PROBLEMS LEADING TO CURRENT NEEDS AND FUTURE OPPORTUNITIES

ELECTRICAL/ELECTRONICS
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KEY FLAMMABILITY ISSUES

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PAST, PRESENT, AND FUTURE FIRE-RETARDANT/RESISTANT REQUIREMENTS FOR MATERIALS USED IN UNDERGROUND COAL MINES

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INTRODUCTION

The Mine Safety and Health Administration (MSHA) is responsible for regulating and inspecting a multitude of surface and underground mining operations to ensure the health and safety of the nation's miners. As part of this charge, the Administration regulates the use of a variety of products used in underground coal mines. Use of many of these products is governed by mandated requirements, which appear in the Code of Federal Regulations (CFR) Title 30. Use of others is controlled by policies or guidelines developed within the agency. The past few years have spawned the development of changes in these requirements for a number of products. These changes were necessitated for several reasons, including the development of new products and technology, experience gained through research and product testing, and the observation of the behavior of existing products in actual mine fires that have occurred over the years.

This paper addresses some of the areas where changes in regulations or policies have recently occurred or are under consideration. Also discussed are selected products or fire protection applications where formal approval requirements do not exist.

SEALANTS

Sealants and foams are generally used in underground mines to prevent spalling, delamination, or sloughage of coal ribs and roof, or to prevent air leakage through seals or stoppings. Formal approval requirements do not currently exist for these classes of materials. Up until 1985, sealants that did not contain any combustible constituents were assigned an acceptance number under a voluntary acceptance program established by the Approval and Certification Center (A&CC) within the agency. A list of acceptable sealants was maintained and distributed to field enforcement personnel and other interested parties. This list provided a useful tool for MSHA personnel responsible for approving mine ventilation plans. A product appearing on the list would not present a flammability hazard since it contained no combustible constituents. Since underground mines demonstrated excellent flame and fire resistant qualities, but suffer from a narrow range of workable application temperatures, limited bonding capabilities, relatively low compressibility, and high friability properties when compared to polyurethane systems.

Future coal regulations are expected to mandate a flame spread index of 25 or less for sealant and foam materials applied in a one dimensional configuration to coal ribs, roof, stoppings, or seals. Other applications may still necessitate a more extensive evaluation.

COMPRESSIBLE BLOCKS FOR STOPPINGS

A rather unique construction application in some underground mines involves the use of compressible or "squeeze blocks" as they are sometimes called. These units are inserted into stoppings constructed from masonry block in areas where floor heave or roof sag is a problem. Stoppings are walls constructed in mines that separate adjacent airways. They are used to course ventilating air to the working areas in the mine where the coal is being extracted. Various designs are used, depending upon the type of convergence experienced by the particular mine. Normally, a course or two of a compressible material, approximately 10-20 cm (4-8 in) high, 20-30 cm (8-12 in) thick is placed between courses of non-resilient masonry block to absorb the loading taken on by the stopping preserving the integrity of the wall. In cases where severe floor heave is prevalent, a large block of compressible material is placed in the bottom-center portion of the stopping (Figure 1). Without this design feature, the stopping will fracture, permitting air to leak into an adjacent airway (Figure 2). There are no formal approval requirements for these types of blocks. In the past, materials exhibiting a flame spread index of 25 or less, as per ASTM E-84 or ASTM E-162, were permitted for such use. Plastic polystyrene, polyurethane, and polyisocyanurate foams with flame-retardant additives were among the more popular varieties.

Recently, the poor performance of these materials in two mine fires has caused the agency to establish new criteria concerning their use [10]. Heat from fires occurring in one airway caused the squeeze blocks to melt or otherwise thermally degrade, allowing smoke and toxic fire gases to spread to the parallel, adjacent airway. In both fires, this adjacent airway served as a designated escapeway for miners working in the mine at the time of the fires.

MSHA now requires that squeeze blocks be able to demonstrate ventilation separation under fire conditions in a manner consistent with incombustible masonry building blocks, tile, or similar materials. Materials used in mine stoppings that do not meet these criteria must be removed and replaced with suitable alternatives or coated with fire-resistant coatings designed to protect the blocks for extended time periods. A large-scale fire test has been developed by the ISD to evaluate these products for fire resistance [11]. ASTM E-119 [12] testing, or equivalent, would also be accepted by MSHA as a method of demonstrating the fire resistance of these products. A one-hour fire rating and flame spread index of 25 or less have been informally established as minimum requirements.

Currently, two plastic foam-type products have been favorably evaluated by the ISD for this application. Both products are in the phenolic family of plastics. These products demonstrate excellent fire-resistant properties, exhibiting char depths of less than 5.0 cm (2 in) when exposed to a flammable liquid test fire generating temperatures 1800 F for one hour. Unfortunately, they tend to be rather friable and not as resilient as their polystyrene and polyisocyanurate counterparts. Their performance in mines experiencing more than 5-10% convergence has been disappointing. There is a great need for a product with the required fire-resistant properties that will behave elastically, like a polystyrene, isocyanurate, or urethane foam, and, at the same time, be impermeable to air leakage.

BRATTICE CLOTH/VENTILATION TUBING

The flammability requirements for brattice cloth and ventilation tubing, outlined in 30 CFR Part 75.302.3 [13], were originally established in 1970. Brattice cloth is used in underground mines to direct ventilating air currents to the working faces in areas where permanent stoppings have not been erected. Typical brattice cloth materials consist of polyethylene (PE), polyvinylchloride (PVC), or jute. Plastic curtains are generally reinforced with nylon or other synthetic scrims.

Ventilation tubing is used to direct fresh air to active areas of the mine where special air requirements are dictated over and above normal ventilation. Ventilating tubing may be rigid (fiberglass-reinforced polyesters) or flexible (PVC with metal-band reinforcing rings or wire).

Title 30 requirements specified that brattice cloth and ventilation tubing be flame resistant to the extent that the flame spread index be 25 or less when tested according to either ASTM E-84 or ASTM E-162. Both of these tests presented difficulties when used as a tool to assess thin brattice and ventilation tube materials. Low melting thermoplastics, such as PE, would melt away from the roof of the tester (ASTM E-84) or melt out of the specimen holder (ASTM E-162) rendering impossible the determination of actual flame spread behavior. In cases where the sample did not completely melt out of the holder, there was still a problem in that the retracted portion of the sample was no longer in contact with the fixed pilot burner. Another inherent problem when testing thin film thermosets was the negligible heat rise upon burning, which resulted in a low heat evolution factor (Q) in the equation for flame spread index as per ASTM E-162. Brattice materials that had high flame spread factors (F_s) would produce low flame spread index values (I_s) because of the low Q factor ($I_s = Q_x F_s$). A final problem was the inherent non-reproducibility experienced when testing these types of materials.

Realizing these problems, large-scale flammability tests were conducted to further investigate the behavior of brattice-type materials under actual end-use conditions [14] [15]. Pieces of brattice cloth, measuring 1.83 m (6 ft) x 7.62 m (25 ft), were suspended vertically in the gallery and ignited with a hand-held moveable burner using methane gas for 30 seconds. Three tests were conducted in still air and three in a ventilating air stream of 0.64 m/sec (125 fpm). The sample failed if any of the following occurred:

1. Flame propagated 3.05 m (10 ft) in any single test.
2. An average duration of burning in either group of tests was one minute or more.
3. Duration of burning was 2 minutes or more in any single test.

Based on this study, a small-scale test was developed by the Approval and Certification Center (A&CC) of MSHA that correlated very well to the results of the large-scale test program (Figure 3). The test exposes 102 cm (40 in) x 122 cm (48 in) samples, vertically hung in a small tunnel to a methane-fueled, impinged-jet-moveable burner. Ventilating air at 0.64 m/sec (125 ft/min) is passed over the sample in three tests and three tests are conducted with no ventilation. The burner is applied to the front lower edge of the brattice cloth and kept in contact with the material for 25 seconds or until 1 foot of material, measured horizontally, is consumed, whichever comes first. In order to be considered flame resistant, the brattice cloth shall meet each of the following criteria:

1. Flame propagation of less than 122 cm (4 ft) in each of the six tests.
2. An average duration of burning of less than one minute in both groups of three tests.
3. A duration of burning not exceeding 2 minutes in each of the six tests.

The test was favorably received by industry and has been found to very effectively discriminate between materials which offer low flame spread rates under actual end-use conditions and those which provided low flame spread values only when tested according to previously described ASTM test methods. This test procedure was promulgated as a final rule in June of 1988 in 30 CFR [16] for testing and approval of brattice cloth (Part 7.27) and ventilation tubing (Part 7.28). The test conditions for rigid tubing vary somewhat from those dictated for brattice cloth. Importantly, large-scale fire testing on ducting [17] has shown good agreement with Part 7.28 procedures.

FLAME-RETARDANT TIMBER

There are no formal requirements for flame retarding of timbers used in underground coal mines at this time. Some applications exist, however, where resistance to surface flame spread is desired. Among these applications are wooden access doors in mine stoppings, wooden doors on underground mine shops, and stopping constructions using heavy timber in areas exposed to heaving conditions. In the past, the Agency has recommended that timber, used in underground coal mines for these applications, be flame retardant as demonstrated by a flame spread index of 25 or less as per ASTM E-84, ASTM E-162, or equivalent. Flame retardant coatings or paints, listed in the Underwriters' Laboratories <u>Building Materials Directory</u> [18], have been determined to be suitable for this application. Flame-retardant products that are not listed in the directory can be tested as per an ASTM or equivalent standard to verify compliance with this recommendation. There are no current plans to change these recommended guidelines.

CONVEYOR BELTS

Present requirements concerning the flammability properties of conveyor belts used in underground coal mines dictate that they be approved as flame resistant under Part 18.65 of 30 CFR [19]. This test exposes four specimens, each 152 mm (6 in) long by 12.5 mm (0.5 in) wide by sample thickness, to a bunsen burner adjusted to give a blue flame, 75 mm (3 in) in height, with natural gas. The burner flame is applied to the free end of a horizontally-mounted specimen in a 53 cm cubical (21 in) test gallery for 1 minute in still air. At the end of 1 minute, the flame is removed and a ventilating fan turned on to provide an air flow of 1.52 m/sec (300 fpm) past the sample. The duration of flame is measured. After the specimen ceases to flame, it remains in the air current for an additional 3 minutes to determine the presence and duration of afterglow.

In order to be considered fire-resistant, tests of the four specimens, cut from any sample, shall not result in either: (1) duration of flame exceeding an average of 1 minute after removal of the applied flame or (2) afterglow exceeding an average of 3-minutes duration.

This approval test was originally developed by the United States Bureau of Mines as Schedule 28 [20] in 1955, became part of Schedule 2G [21] in 1968, and was mandated as part of the Coal Mine Safety and Health Act of 1969 [22]. Much as been learned about the fire-resistant qualities of conveyor belts in fire situations over the past several years. This experience has been in the form of both large- and full-scale fire test programs and actual fires that have occurred in underground mines. The data generated suggests that the 2G test is not always a reliable indicator for predicting the flammability behavior of conveyor belt under actual end-use conditions. This problem was demonstrated by Mitchell [23], Warner [24], and, more recently, Lazzara [25] and Verakis [26], who reported on the results of large- and full-scale tests of approved conveyor belts where propagating fires were developed under controlled conditions. Additionally, over a 19-year period, a total of 14 fires were reported by MSHA [27], which involved burning of significant lengths, 15.0 m (50 ft.) or more of conveyor belting.

The realization that the current approval test method was subject to inherent difficulties in predicting the real world flammability properties of conveyor belt materials lead MSHA to request the U.S. Bureau of Mines (USBM) to develop an improved fire-resistance belt test [28]. The general design of this apparatus was based upon data from full-scale test fires conducted under a USBM contract [29]. However, this test was not accepted by MSHA as a replacement for 2G.

More recently, the A&CC requested the USBM to conduct a large-scale fire test program to further study the problem. Data from the large-scale test program was then used by the USBM to develop a laboratory-scale apparatus for evaluating the fire resistance of conveyor belts [30]. The new test [31], shown in Figure 4, correlates well with the large-scale test results.

The test exposes a 1.52 m (5 ft.) long by 0.23 m (9 in.) wide sample of belt, mounted in a ventilated tunnel to a 12 jet-methane gas ignitor, burning 35 liters per minute (1.25 cfm) for a 5-minute period. Air current of 1.02 m/sec (200 fpm) flows past the sample. The belt passes the test if, in three separate trials, there remains a portion of the sample that is undamaged across its width. A belt fails the test if, in any single trial, fire damage extends to the end of the sample.

The more stringent requirements on belt flammability properties imposed by this test may, in some cases, necessitate development of new and improved formulations for flame retarding traditional belt materials, such as PVC, styrene-butadiene, or neoprene rubbers. Strategies involving cover treatment, carcass, or fabric treatments, or combinations of both, are currently being investigated by belt manufacturers.

Currently, an interim testing program is being conducted by MSHA's A&CC in conjunction with the USBM, which enables belt manufacturers to test various flame-retardant formulated plastic and rubber belts [32]. There is no charge to the manufacturers for this testing under the program. A voluntary acceptance program is targeted for December of 1989, during which a fee will be charged. Concurrent with the implementation of the voluntary acceptance program, MSHA intends to enter rule-making to prepare regulations requiring use of conveyor belts with enhanced flammability characteristics in all underground coal mines.

SUMMARY

This paper has attempted to address selected mining products where recent changes in flammability or fire-resistant requirements or guidelines have occurred. These changes may necessitate a re-design or reformulation of the particular products involved. All organic materials, even those that contain flame-retardant additives, will burn if exposed to enough heat and enough oxygen for a long enough period of time. It is the function of the compounder to develop suitable, yet cost-competitive, formulations, which will result in the product's conformance to the applicable performance standards. The recent changes in MSHA's philosophy concerning these products should provide new and challenging opportunities in the field of flame-retardant chemistry and fire-protection engineering.

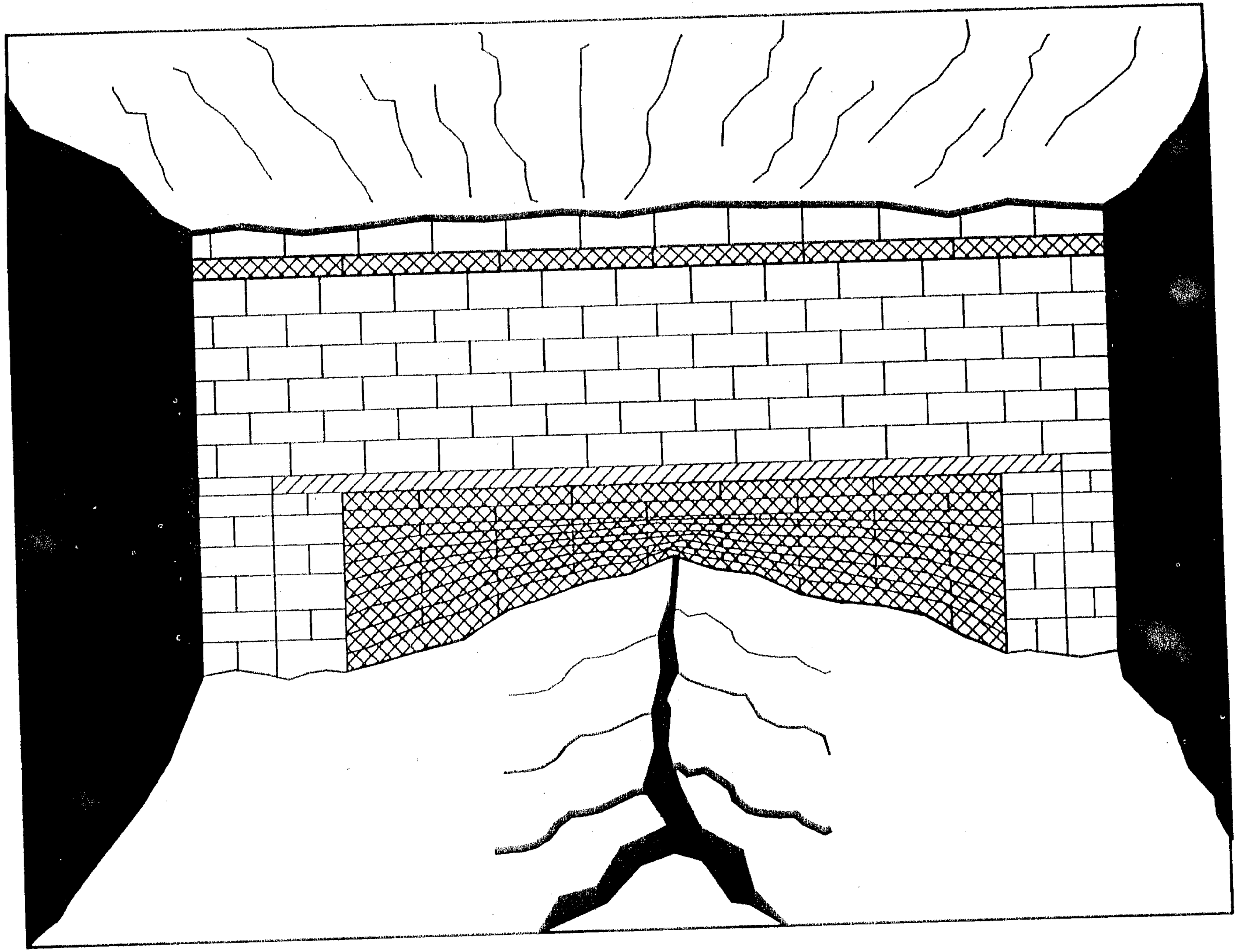


FIGURE 1 — MASONRY BLOCK STOPPING
WITH SQUEEZE BLOCK CRIB

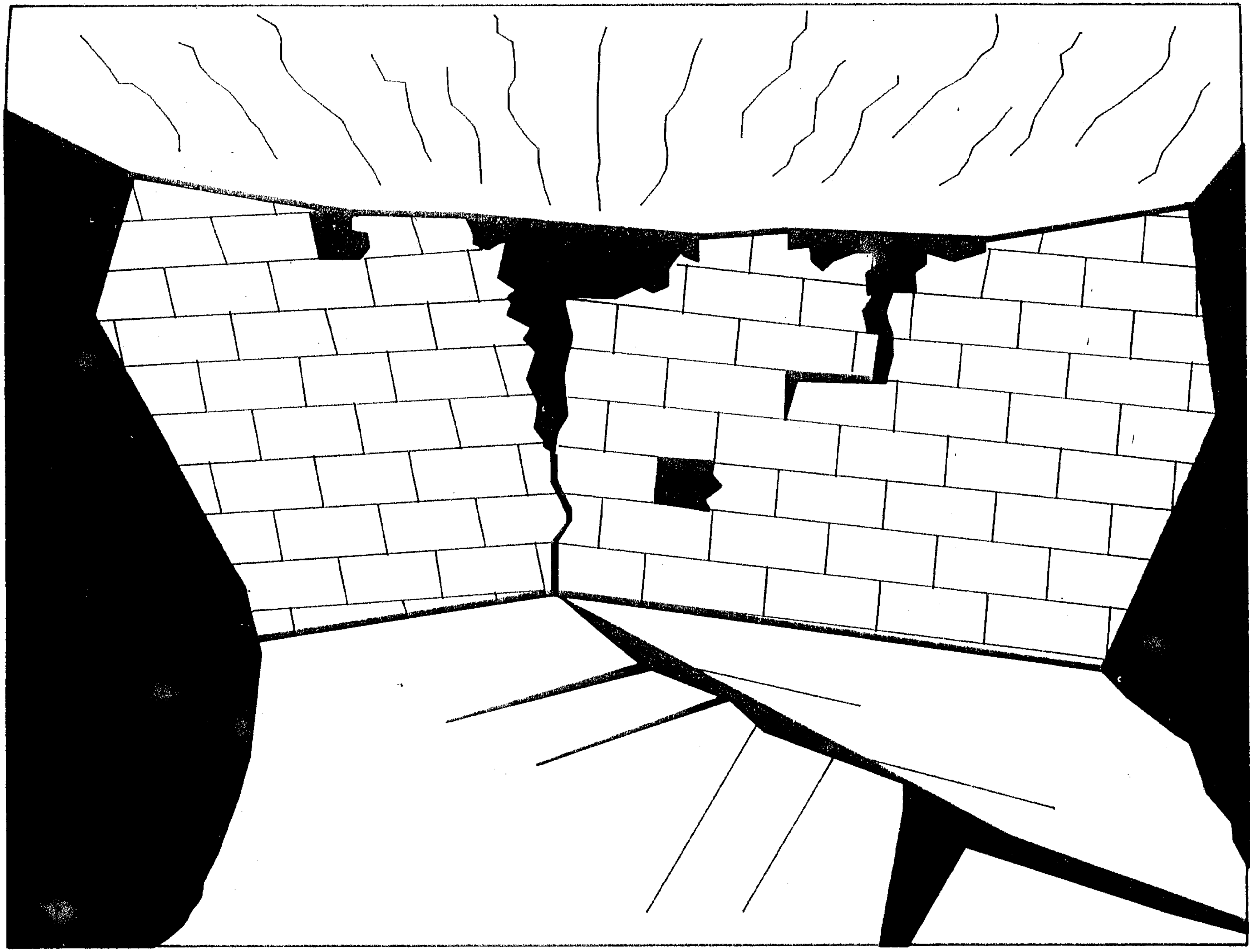
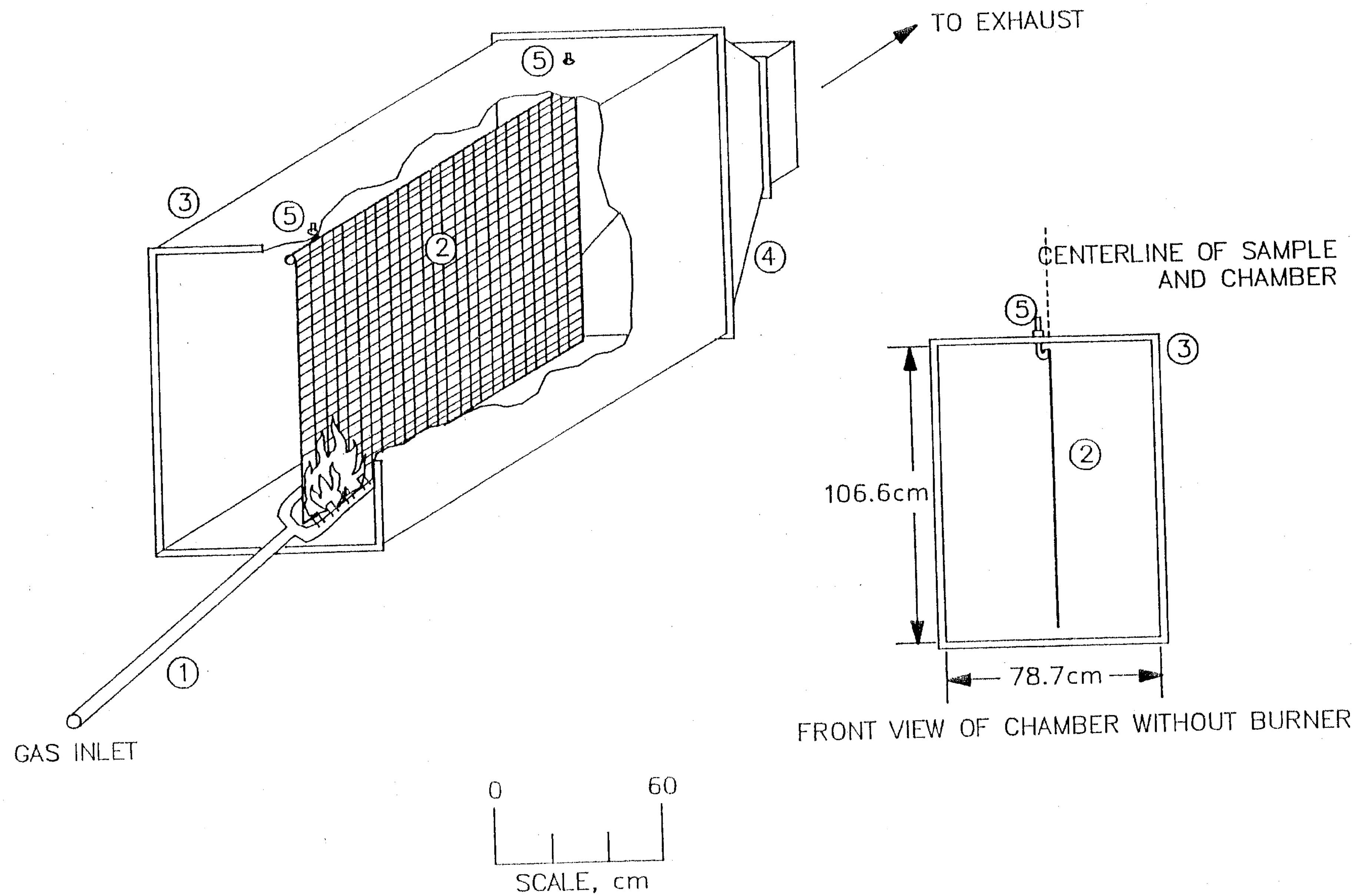
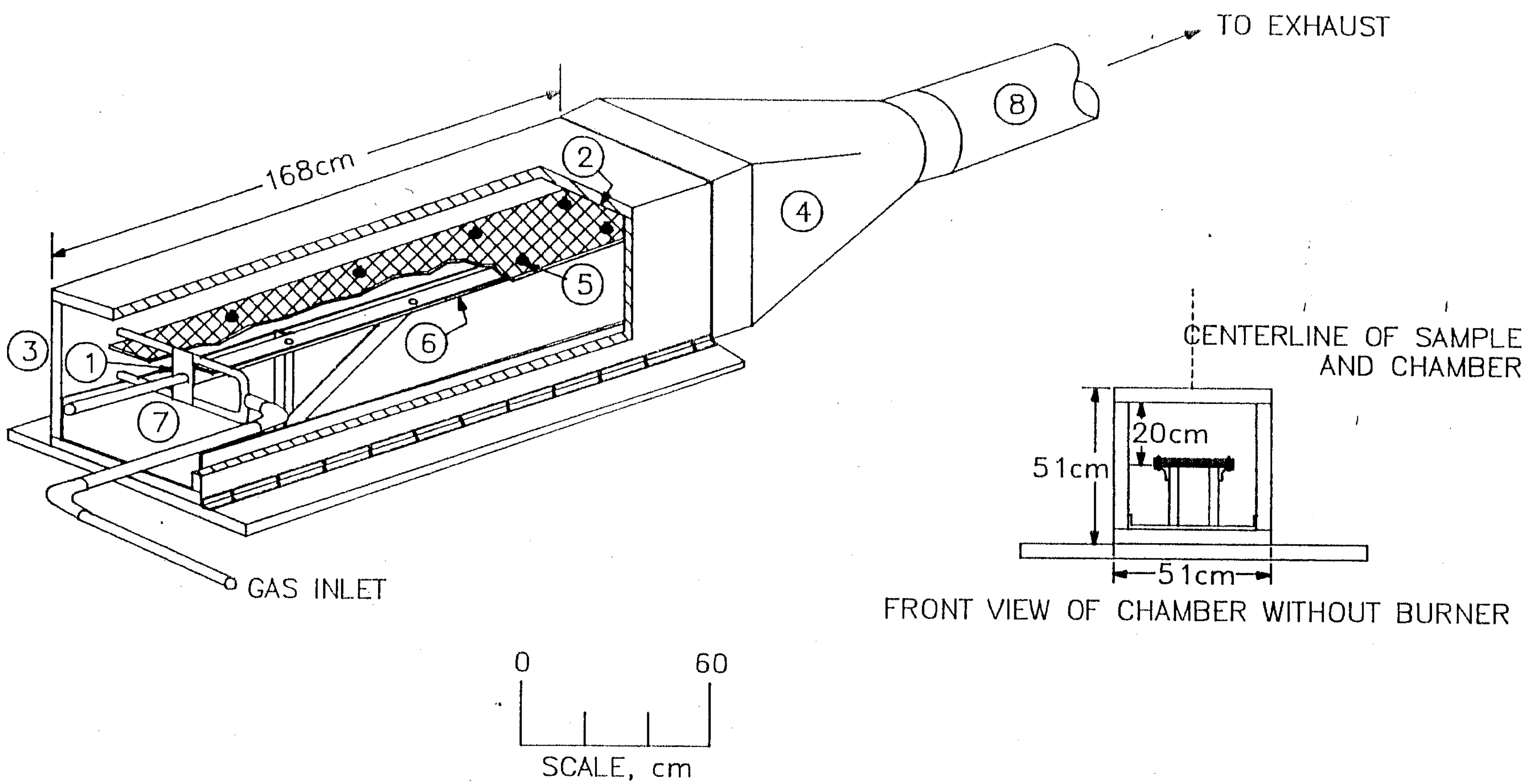


FIGURE 2 – CONVENTIONAL MASONRY BLOCK STOPPING EXPERIENCING FLOOR HEAVE



KEY
1. MOVABLE BURNER
2. SAMPLE (102 by 122cm)
3. TEST CHAMBER (1.3cm THICK REFRACTORY MATERIAL)
4. TAPERED DUCT
5. SUPPORT RODS

FIGURE 3 – SMALL SCALE FLAMMABILITY TEST FOR BRATTICE CLOTH
(Courtesy of M.S.H.A. – A.&C.C.)



KEY
1. BURNER
2. BELT SAMPLE (23 BY 152cm)
3. TEST CHAMBER (2.5cm THICK REFRACTORY MATERIAL)
4. PLENUM
5. BELT FASTENER
6. BELT RACK
7. DEBRIS TRAY
8. EXHAUST DUCT

FIGURE 4 – BELT EVALUATION LABORATORY TEST
(Courtesy of U.S.B.M.)

19. U.S. Code of Federal Regulations. "Title 30 - Mineral Resources," Chapter I - Mine Safety and Health Administration; Department of Labor Subchapter B - Testing, Evaluation, and Approval of Mine Products; Part 18 - Electric Motor-Driven Mine Equipment and Accessories; Subpart 18.65 - Flame Test of Conveyor Belting and Hose; July 1, 1988, p. 110.
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31. "Fire Testing Procedures and Construction Drawings for the Belt Evaluation Laboratory Test," Developed by USBM's Pittsburgh Research Center (PRC) for MSHA's A&CC, March 1989.
32. Minutes of Public Meeting on MSHA's Conveyor Belt Flammability Program, U.S. Dept. of Labor, MSHA's A&CC, Triadelphia, W.Va. 26059, March 15, 1989.